

**MANUFACTURING A DENTAL IMPLANT DRILL GUIDE
AND A DENTAL IMPLANT SUPERSTRUCTURE**

Related Application

[0001] This is a Continuation In Part of United States Patent Application No. 09/595,921 filed on June 16, 2000, which is a continuation of United States Patent 5,725,376 filed on February 26, 1997 and issued on March 10, 1998, and which is, in turn, a continuation of PCT Application No. PCT/CA97/00984.

Field of the Invention

[0002] The present invention relates to a method of manufacturing a dental implant drill guide. The invention also relates to a method for the reconstruction of an edentulous jawbone.

Background of the Invention

[0003] It is known in the art to secure dental prostheses using dental implants secured in the upper or lower jawbone. It is also known in the art to mount a framework or superstructure to a number of implants, the superstructure being used to evenly support a set of false teeth or denture prostheses. Accurate placement within the jawbone of the implants is a difficult task. In International Patent Application No. PCT/IT94/00059, published 24 November 1994 as WO 94/26200, there is described an adjustable guiding device for positioning dental implants in which it is possible for the dental surgeon to adjust a drill axis for each implant before proceeding to use the guiding device or drill template to guide the surgeon's drill for the purposes of preparing the drill hole for the implant. The guiding device disclosed in the International publication helps the dental surgeon to decide on the drill axis after

viewing radiographic images of the radio-opaque tubular drill guide superposed the bone structure.

[0004] In the known prior art, the oral surgeon typically has difficulty deciding on a drill axis for the implants since the ideal position for the implants should be decided with knowledge of the jawbone structure into which the implant is to be inserted, knowledge of the position within the jawbone structure of the nerve tissue, the gum surface and the required position and dimensions of the false teeth or dentures to be supported by the dental implant. Of course, in the conventional manner of selecting the implant axis, the dentist or dental surgeon simply makes a best guess in light of his knowledge of the patient. Of course, this leads, in certain cases, to imperfections in the dental prosthesis. The imperfections may be lack of ideal support, unfavorable angulation of an implant causing a weakness in the implant which may cause failure over time, or a visually perceptible defect in the appearance of the prosthesis.

[0005] In the conventional method for the construction of the superstructure, a physical model of the patient's gums and dental implant heads is prepared on which the superstructure is built manually using molding and other techniques known in the art. The craftsman or technician skilled at manufacturing such dental superstructures takes into consideration the size and shape of the desired dentures to be placed over the superstructure when crafting the same. The procedure for manufacturing dental implant superstructures as is conventionally known in the art is time-consuming and sometimes results in imperfect structures or defects in the visual appearance of the dentures to be placed over the superstructure.

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[0006] In U.S. Patent 5,401,170 granted March 28, 1995 to Nonomura, there is disclosed a method and apparatus for measuring by camera image the implant heads of the implants in the patient's mouth for the purposes of cutting a frame on which the prosthetic teeth will be arranged and baked. In the method disclosed, the construction of the frame or superstructure is carried out in the absence of a reference to the shape and position of the patient's ideal teeth position. Thus, as the dentures or artificial teeth are crafted on the frame or superstructure, care would be required during the manual process to ensure that the position of the teeth on the frame will match the opposed set of teeth in the patient's mouth.

[0007] Known techniques also have the disadvantage of necessitating two separate sessions to install the implants and the superstructure. It would be highly beneficial to be able to prepare the superstructure prior to the surgery so that the implants and the superstructure are installed during the same surgical procedure.

Objects of the Invention

[0008] It is a first object of the present invention to provide a method of manufacturing a dental implant drill guide or drill template which will result in a precise and accurate drill guide for selected drill holes.

[0009] It is furthermore an object of the present invention to provide a method of manufacturing a dental implant superstructure in which information concerning the position of a plurality of dental implants mounted in a jawbone, the gum surface covering the jawbone and the fixed denture shape is

all taken into consideration during the specification of the shape of the superstructure before the superstructure is precision made.

[00010] It is yet another object of the present invention to provide such methods which provide better accuracy and faster results than conventional methods.

[00011] It is yet another object of the present invention to provide a dental implant drill guide which is precise and easy to use such that drilling of the dental implant holes does not require expert skill and knowledge beyond the skill of basic dental surgery. It is furthermore an object of the present invention to provide tools which will reduce the number of visits a patient needs to make to the dental surgeon in order to have dental implants and a dental implant superstructure inserted.

Summary of the Invention

[00012] According to a first aspect of the invention, there is provided a method of manufacturing a dental implant drill guide, comprising the steps of: imaging a jawbone and tissue structure with a reference to a known anatomical reference to produce a three-dimensional computer graphics model; selecting at least one implant drill hole position for at least one dental implant using said model, said position being specified in three dimensions, including a hole termination point and orientation, and being referenced to said anatomical reference, entering at least one set of implant drill hole position coordinates into a computer controlled precision manufacturing device; providing a drill template body having a first surface adapted to overlies a gum surface of the jawbone in a single predetermined position; using said precision manufacturing device to

provide a fixed orientation drill guide socket in said template body for each one of said at least one drill hole position with a corresponding position and orientation.

[00013] According to a second aspect of the present invention, there is provided a method for allowing the reconstruction of an edentulous jawbone in a single surgical operation, comprising the steps of: a) creating a three-dimensional graphic computer model of a patient's gum, jawbone and tissue structure, and of a dental prosthesis to be placed over the gum; b) selecting a number of virtual implant drill holes positions for corresponding implants using said model; c) entering data related to the virtual implant drill hole positions into a computer controlled precision manufacturing device; d) providing a rigid drill template body; e) using said precision manufacturing device to provide a fixed orientation socket in said drill template body for each one of said implant drill hole positions selected in step b); f) prior to the surgical operation, using said data on said virtual implant drill hole positions and said precision manufacturing device to make a dental implant superstructure having a number of dental implant abutting flanges interconnected by a bridge in a fixed configuration in which said dental abutting flanges are positioned in accordance with the virtual implant drill hole positions; g) using said drill guide to drill pilot holes in the patient's jawbone at said virtual implant drill hole positions; h) inserting an implant in each of said pilot holes; and i) installing the dental implant superstructure prefabricated in step f) on the implants inserted in the patient's jawbone.

[00014] In the method of manufacturing a dental implant drill guide according to the present invention, the patient is typically edentured, namely, the patient has had all teeth pulled from the jawbone, and the jawbone has been given time to heal since the teeth were pulled. If the patient decides to proceed with dental implants and the placement of a superstructure for solidly securing dentures over the gum, a period of about 1 month is provided for from the time of pulling any remaining teeth from the jawbone before proceeding with the operation of inserting implants into the jawbone.

[00015] A medical image of the jawbone and tissue structure is obtained by using x-ray imaging, MRI or possibly nuclear imaging techniques to produce a three-dimensional computer graphics model which has a reference to the gum surface or some other fixed reference with respect to the patient's jawbone. Preferably, a radiographic scanner guide is used which is molded to conform to the shape of the patient's gums and which includes radio-opaque spheres whose positions with respect to the gum surface is known.

[00016] The primary advantage of the invention is that the oral surgeon may select the optimum position for dental implants using the three-dimensional computer graphics model of the jawbone and tissue structure. Selection of the drill hole positions using the computer graphics model is transferred to a CNC device for the purposes of providing fixed drill guide sockets in the template body for each one of the drill hole positions or position selected using the computer graphics model. While the model is three-dimensional, it may be convenient for the purposes of selecting the drill hole axis to use a two-dimensional

representation of the jawbone and tissue structure, the two-dimensional view being displayed with a user controlled slice angle. Preferably, the dental surgeon will select the position for each implant drill hole, not only to position the implant in the optimum location within the jawbone, but also to result in a position of support which is suitable for supporting the dentures. Therefore, it is preferred to display, in addition to the three-dimensional computer graphics model of the jawbone and tissue structure, the patient's dentures in the proper spatial relationship with respect to the jawbone and tissue structure. This requires imaging the patient's dentures or teeth, and possibly gum structure, in addition to the jawbone and tissue structure, in such a way that all images are referenced with respect to one another to be integrated into the same three-dimensional computer graphics model.

[00017] While it would be possible to prepare the drill template body and provide it with the drill guide sockets using the CNC device, the drill template body is preferably molded on a physical model of the gum surface into which model the CNC device has previously drilled the desired implant drill holes. The drill holes in the physical model are used to build a mold for the drill guide sockets. This prevents the need to use the CNC device to produce fine details except for the precision drilling of the drill holes.

[00018] Imaging of the dentures or teeth to be placed over the gum surface and the imaging of the gum surface can be carried out by using laser camera imaging techniques known in the art. These images are preferably obtained using a physical model of the

patient's gum surface, and the physical model is imaged in such a way that the images can be referenced accurately to the jawbone and tissue structure images.

[00019] According to one method of manufacturing the dental implant superstructure, the actual dental implant position data is obtained by taking an imprint using transfers connected to the implants. Preferably, the imprint is taken using the same drill guide with the sockets of the drill guide being large enough to receive the transfers and surrounding imprint material. Preferably, the positions and orientations of the transfers are physically measured along with a reference to the drill guide which will permit the relative positions of the implants to be known with a reference to a standard frame of reference. Using the standard frame of reference, it is possible to generate a computer graphics model of the gum surface, dentures or teeth and dental implants which allows the dental surgeon or technician to select the best shape for the overlying bridge of the superstructure.

[00020] According to a further general aspect of the present invention, the implant drill hole positions selected using the computer graphics model can also be used to make the superstructure. By so using the planned implant positions, instead of taking an imprint of the implants inserted in the patient's jawbone to precisely determine their actual locations in relation to the jawbone, the superstructure can be made prior to the surgical operation, i.e. prior to the insertion of the implants into the patient's jawbone. This advantageously provides for the installation of the implants and the superstructure in a single surgical operation. This novel approach of creating a superstructure on the basis of the virtual

positions of the dental implants selected using the three-dimensional computer graphic model of the jawbone and the dental prosthesis has the following advantages for the surgeon:

- [00021] - no need for taking imprints of the implants to determine their positions in the jawbone;
- [00022] - no need for a second surgical procedure to expose the head of the implants;
- [00023] - improved stability of the implants, as they are immediately interconnected to each other by the superstructure;
- [00024] - improved protection of the implants, since they are better stabilized;
- [00025] - less sessions with a patient, thus, higher profitability;

[00026] and the following advantages for the patient:

- [00027] - only one operation and, thus, less traumatism;
- [00028] - accelerated healing because of the protection afforded by the superstructure;

[00029] In the case of a fixed dental prosthesis which is implant mounted (i.e. porcelain on metal), the ideal form of the superstructure can be automatically designed using the computer model taking into consideration the form of the laser camera imaged teeth and by subtracting a thickness of porcelain which the technician requires to recreate the shape of the imaged teeth. In the case of a dental prosthesis supported by a superstructure (overdenture), the shape of the superstructure can be automatically determined by taking into account the external shape of the prosthesis and by circulating the superstructure

inside the prosthesis, making sure that the necessary thickness of prosthesis material (e.g. acrylic) will be available all around in order to provide a adequately strong prosthesis.

[00030] When precision forming the superstructure, it is possible to use various techniques. In one embodiment, the entire superstructure is cut using a CNC milling machine programmed to cut according to the shape data specified using the computer model.

Brief Description of the Drawings

[00031] Other objects and features of the present invention will be better understood by way of the following detailed description of the preferred embodiment with reference to the appended drawings in which:

[00032] Figure 1 is a perspective view of an articulator supporting a physical model of a patient's upper and lower gums with dentures in place;

[00033] Figure 2 is a perspective view similar to Figure 1 in which the dentures have been replaced by a radiographic scanning guide;

[00034] Figure 3 is a perspective view of the radiographic scanning guide;

[00035] Figure 4 is a perspective view of a three-dimensional computer model of a patient's lower jawbone shown partly broken away with the radio-opaque reference spheres and reference coordinate superimposed;

[00036] Figure 5 is a flow diagram of the method of manufacturing the dental implant drill guide according to the preferred embodiment;

[00037] Figure 6 is a panoramic view of a lower jawbone of a patient with the gum line and dentures superimposed;

[00038] Figure 7 is a cross-sectional view about line 7 of Figure 6;

[00039] Figure 8 is a block diagram of the CNC drill device and data entry terminal;

[00040] Figure 9 is a perspective view of a five axis CNC drill device;

[00041] Figure 10 is a front view of a physical model with four drill axes shown;

[00042] Figure 11 is a view similar to Figure 10 in which a drill guide has been molded with the fixed drill sockets formed by pins inserted in the drill holes;

[00043] Figure 12 is a perspective view of the drill guide according to the preferred embodiment;

[00044] Figure 13 is a sectional view of the drill guide being used to drill a patient's jawbone;

[00045] Figure 14 is an enlarged sectional view of a jawbone having received an implant with the drill guide placed on top of the gum surface to act as an impression tray for the purposes of taking an exact imprint of the implant position using a transfer;

[00046] Figure 15 is a sectional view of a computer model illustrating the denture fit over the patient's gums with the implant head in correct relative position;

[00047] Figure 16 illustrates a similar computer graphics image as in Figure 15 for a position between two implants;

[00048] Figure 17 illustrates a perspective view of lower dentures and a lower superstructure; and

[00049] Figure 18 is a view from underneath the assembled components illustrated in Figure 17.

Detailed Description of the Preferred Embodiment

[00050] As illustrated in Figure 1, an articulator 20 as is known in the art is set up to support a lower physical model 21 and an upper physical model 22 of a patient's mouth with lower and upper dentures 23 and 24 supported by the physical model with the teeth of the dentures in proper alignment. The articulator is adjusted using the adjustment means 25 and 26 as is known in the art. As illustrated in Figure 2, the dentures 23 and 24 are removed and a scanner guide 27 is made by hand to fit exactly the space occupied by the upper and lower denture. Radio-opaque reference spheres 28 having a known diameter are bonded to the guide 27 with one sphere on each side at the rear and one in the front. In the illustration in the preferred embodiment, the spheres are shown near the lower jaw surface since it is the lower jaw that is to be imaged. The spheres could likewise be placed near the upper jaw surface as the case may be. The separated scanner guide body 27 is illustrated in Figure 3.

[00051] The particular advantage of the scanner guide 27 according to the present invention is that during radiographic scanning of the patient's jaw, the patient may comfortably hold the scanner guide 27 in place by closing down on the same. As can be appreciated, the lower jaw could move during imaging and must be secured by means such as the scanner guide 27. The patient's head is held in place during radiographic scanning using a suitable brace as is known in the art.

[00052] As shown in Figure 4, the result of the radiographic scanning is to obtain a three-dimensional computer graphics model 29 of the patient's lower jaw.

Images of the reference spheres 28 appear as 33 and provide a reference to a coordinate axes 32. The dental surgeon is capable of viewing with the model 29 the nerve 37 which extends from the base of the jaw until it exits the jawbone at each side of the chin. A drill axis 31 for each proposed drill hole 34 is selected on the computer model. The end point of the drill hole 36 is also selected.

[00053] For ease of selection of the drill axis 31, namely the position in space of the end point and the angular orientation of the drill axis 31, it may be possible to present slices of the computer model 29 to the dental surgeon or technician which would make it easier to select the parameters. As can be appreciated, two angles are required to specify the orientation of the drill axis 31, for example, a first angle θ may define an angle of the drill axis 31 with respect to the x-z plane and a second angular parameter ϕ may define the angle between the drill axis 31 in the z-y plane.

[00054] In the preferred embodiment, selection of the drill axes 31 for the drill holes 34 is done with knowledge of the relative position of the gum surface and the relative position of the dentures or teeth. As illustrated in Figure 5, the 3-D computer model 29 is built up using the radiographic 3-D imaging data as well as referenced gum surface image data and referenced denture image data. In Figure 6, there is shown a panoramic slice view of the 3-D model 29 showing the gum surface 44 and dentures 43 superposed the cortical bone structure 41 and the marrow 42.

[00055] As illustrated in Figure 7, in the preferred embodiment, it is possible to view for a selected

drill axis 31 the resulting implant position 49 and how this relates to the bone structure 41 and 42, the nerve 37, if present, as well as the lower and upper denture structure 44 and 43. As can be appreciated, if the desired angle and position of the dentures with respect to the gum surface 46 would require an adjustment of the position and angle of the implant 49, the dental surgeon is able to select the optimum depth, position and angular orientation for the implant 49 relying entirely on the computer model. Once the hole termination position and angular orientation data for each of the drill holes is selected using the computer model, the data is entered through a data entry device 51 to control a CNC drill 52 in accordance with Figure 8 and as better illustrated in Figure 9.

[00056] The CNC drill 52 has a drill bit 53 which is capable of moving and drilling along a first vertical direction 54. The physical model 21 is mounted in such a way that it is able to turn about two directions 55 and 56 on a platform which is able to move in directions 57 and 60. The CNC drill 52 is capable of moving about five axes. In order for the CNC drill device to be properly referenced with respect to the physical model 21, the scanner guide may be placed on top of the physical model 21 and a coordinates measuring machine (CMM) connected to CNC drill 52 is used to accurately locate the position of each one of the position reference spheres and reference these to the CNC drill's reference frame. The CNC drill 52 is then programmed to convert the hole position and orientation data as referenced to the frame of reference of the computer model to the

reference frame of the CNC drill so that the drill holes may be prepared in the physical model 21.

[00057] As illustrated in Figure 10, four drill holes 58 are cut into the physical model 21 which is mounted on a base 59. The drill hole axes 31 as shown are in different positions and orientations.

[00058] As shown in Figure 11, rods 62 are inserted into the holes 58. The socket forming mold parts 63 are placed over the rods 62 and a surrounding mold structure (not shown) is placed around the physical model 21 to allow for the molded guide body 61 to be formed. Since the holes 58 are of different heights, the socket forming mold parts 63 are adjusted in size such that the distance between the circular flange edge and the end of the rods 102 is a constant. In this way, the circular flange edge 64 of the drill guide sockets is at a fixed distance with respect to the desired end point of the drill hole.

[00059] As shown in Figure 12, the finished molded drill guide body 61 has a plurality of drill guide tubes 66 inserted into the drill guide sockets 68, and three holes 67 are additionally provided for transitionally securing the drill guide 61 to the patient's jawbone during surgery. The drill guide tubes 66 may be removed and reinserted into the drill guide sockets 68 in order to change the internal diameter of the drill guide tubes as is required during surgery since the implant drill hole is started with a very small diameter drill bit and subsequently larger drill bits are used until the full size implant drill hole is obtained. As shown in Figure 13, the drill used in surgery is provided with a collar 69 for abutting against the upper surface of the guide tube

66 in such a way that the distance between the bottom of the collar 69 and the end of the drill bit 71 is fixed as required. In the preferred embodiment, the collar 69 is integral with the drill bit 71.

[00060] As can be appreciated, the oral surgeon prepares the implant holes using the drill guide 61 by removing circular portions of the gum (gingival taps) at the implant sites. In the conventional method of drilling implant holes, a procedure known as "flap surgery" is carried out in which a piece of the gum covering the jawbone where the implant hole is to be drilled is cut and peeled back so that the oral surgeon has clear access to the jawbone surface. Using the present invention, the surgeon has the option of doing flap surgery if required or circumferential surgery as needed. Of course, if a conventional flap surgery is to be done, a modification of the surgical guide should be done, i.e. the guide should be removable as needed for flap surgery. In order to put the guide back at the same location, the use of transitional implants is needed to seat the guide after the flap is done. If the circular approach is chosen, there is no need to remove the guide during surgery, and by avoiding flap surgery, post operation healing time should be reduced.

[00061] As illustrated in Figure 14, the oral surgeon screws in an implant 72 into the hole made using drill guide 61. This can be done with the drill guide 61 remaining in place, the implants being inserted through the sockets 68. The upper surface of the implant 72 is approximately flush with the upper surface of the cortical exterior 41 of the jawbone. The implant 72 has a hollow threaded core. Since the

implant 72 has been inserted into the jawbone tissue 42 by hand, its exact position may not be perfectly defined by the drill hole formed using the drill guide 61. It has been found that this problem can be overcome by leaving the drill guide 61 in place during the implant insertion and by rigidly connecting each implant 72 to the guide 61 once fully inserted in the patient's jawbone. The screwdriver (not shown) used by the surgeon to screw the implants 72 into the implant holes is provided with a collar for abutting against a corresponding abutting surface (not shown) at the entry of each socket 68 in such a way that the distance between the abutting surface and the bottom of the socket 68 be precisely fixed as required. In this way, the surgeon will insert a first implant 72 in one of the sockets 68 located at a first end of the drill guide 61 and screw the implant 72 into the corresponding drill hole until the abutment on the screwdriver contacts the abutment at the entry of the socket 68. Once fully inserted, the implant 72 is securely fixed to the drill guide 61 by means of an anchoring screw tightened into the implant 72. Then, a second implant 72 is inserted into another socket 68 located at a second end of the drill guide 61 opposite the first end thereof and is screwed into the corresponding drill hole in the same manner as for the first implant 72. A second anchoring screw is then screwed into the second implant 72 to rigidly connect the same to the drill guide 61. The other implants are subsequently installed following the same procedure. Once all the implants 72 have been inserted, the relative position of each implant 72 with respect to its neighbors should not have changed as long as the

drill guide 61 was not subject to any deformations during the installation of the implants 72. Indeed, it is important that the drill guide 61 be capable of sustaining elevated torsion forces in order to ensure that the actual position of the implants 72 precisely corresponds to that selected on the computer model. For instance, the drill guide 61 could be made from a rigid metallic structure or from any other structural material offering a high level of rigidity.

[00062] By so using a rigid drill guide in the installation of the implants, it becomes possible to precisely insert the implants in the patient's jawbone at the positions selected on the computer model. This advantageously obviates the need for taking an imprint of the implants to determine their actual positions in view of the fabrication of the superstructure to be attached to the implants.

[00063] Due to this new level of precision in the positioning of the implants, the superstructure can be fabricated prior to the surgery using the implant positions selected on the 3-D computer model of the patient's jawbone, gum and dental prosthesis.

[00064] As shown in Figure 16, the implant head 49 will receive a superstructure consisting of an abutment foot 47 extending down to the top of the implant and having an upper bridge-like structure 48 extending inside the lower portion 44 of the denture structure and even possibly into the upper portion 43 of the denture structure. In between two implants, as illustrated in Figure 17, the bridge structure 48 is designed to be located above the gum surface 46 and within the denture structure. As can be appreciated, due to the confines and configuration of the patient's mouth, it may be necessary to shape the bridge

structure 48 such that it passes close to either an inner or outer side wall of the denture structure 43, 44. In this way, the denture technician is capable of viewing in the computer model how the bridge structure and superstructure is best constructed.

[00065] Once the denture technician has selected the shape for the dental implant superstructure and the position of the implants using the computer model, the shape data is passed on together with the data on the selected implant positions to a precision forming device for shaping the superstructure. In the preferred embodiment, a CNC milling machine similar to the CNC drill device illustrated in Figure 9 is used. The result is a superstructure, as illustrated in Figure 17, that can be fastened directly to the dental implants in a one-stage surgical procedure. That is to say, the implants and the pre-manufactured superstructure can be installed during the same surgical procedure. Since the abutment feet 47 of the superstructure and the sockets 68 in the drill guide 61 are machined using the same virtual implant position data and since the implants 72 are prevented from moving in the patient's jawbone by the drill guide 61, the abutment feet 47 will fit perfectly on the implants 72 screwed into the patient's jawbone, thereby allowing the superstructure to be prepared before the implants 72 are actually inserted into the patient's jawbone.

[00066] The superstructure illustrated in Figure 17 is of the type which receives dentures by snap-fit. The superstructure is prepared from a solid piece of commercially pure titanium or any biocompatible material such as porcelain, preventing corrosion between implants and superstructure.